A PARTICLE SIZE AND CHARGE ANALYZER FOR INVESTIGATION OF THE ELECTRICAL PROPERTIES OF DUST DEVILS

Final Report

JPL Task 980

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A. OBJECTIVES

The objectives of the proposal were to develop an end-to-end electromechanical system for the simultaneous analysis of the size and charge of dust-sized particles at a high sampling rate. This included integration of pumping technology, signal-processing electronics, and data-analysis and display software. Included in the objective was to develop the measurement technique to the point where we could credibly propose for future funding from NASA instrument development programs.

B. PROGRESS AND RESULTS

1. Description of the new instrument.

The heart of the particle charge spectrometer (PCS) is a hollow metal tube, which serves as a Faraday cage, connected to the low-noise input transistor of a charge-sensitive preamplifier. A glass capillary (see Fig. 1) guides particles through the tube with a high-speed gas flow induced by a small air pump. Individual particles passing through the sensor generate pulses with amplitude proportional to the charge and width inversely proportional to particle velocity. Signals are analyzed with analog circuitry in the pulse-processing unit (white box in Fig. 2) that reduces each particle event to a pair of voltage values representing charge and transit time. These are digitized and relayed to a laptop computer for immediate display. A power supply completes the system (schematic illustrated in Fig. 3). The PCS requires about 1 watt each for operation of the preamplifier and the air pump. The major power consumption in the instrument is the micro-computer. In the next version of this device, the laptop computer will be replaced with low-power data-logging circuitry.

Because dust particles in the tube are accelerating, their speed at the position of measurement can be related to their aerodynamic diameter, which is a function of particle drag and inertia (Fig 4). A measure of particle size is obtained from each particle event, and is displayed in real time along with the particle charge in a plot of charge vs. size, as indicated in Fig. 5. The data acquisition, analysis, and display system is implemented with LabView software.

The PCS has been used to measure charge on a variety of dispersed dust samples in the laboratory including the JSC-1 Mars soil simulant. The data illustrated in Figure 6 were acquired in the vicinity of a dust devil during the 2002 MATADOR campaign organized by the University of Arizona.

C. SIGNIFICANCE OF RESULTS

This task developed an end-to-end particle sample and measurement system capable of meeting measurement requirements. While the particle charge spectrometer (PCS) developed is capable of being deployed for field operations, it was only demonstrated in this way on a limited basis, with a handful of data sets collected in the Arizona desert. During prolonged periods of operation, the sensor head was susceptible to overheating in the 105°F temperatures encountered in those tests. Nevertheless, the preliminary observations confirm the predicted charge/size signature of particles in a dust devil. We have since altered the sensor design to reduce the temperature susceptibility. For the case of Mars, this sensitivity to warm temperatures will not be a problem.

The results indicate that the size and charge of dust particles can be measured at a rate greater than 100 particles per second. The minimum charge that can be detected on a particle of any size is 300 electrons with a noise level of 100 electrons. The instrument yields size information for particles in the range from 2 – 200 micrometers. The charge sensitivity of the PCS is at least 1000 times better than the next closest instrument of its type. Most single-particle charge-sensing devices developed for meteorology investigations have historically displayed sensitivities that are 100,000 times weaker than that of the PCS. This capability of the instrument represents a quantum leap forward in measurement capability. In sensitivity and speed, the PCS is matched only by the ESPART analyzer [1], a large instrument strictly intended for laboratory use. One drawback of the PCS approach is that it can only measure particles above the 300 electron threshold limit. Particles with less charge cannot be detected or sized.

The most significant result of research was the demonstration of the technique with a small, field-portable instrument requiring just a few watts of power. This demonstration was fundamental to the success of our Mars Instrument Development Program proposal. That proposal will follow on the groundbreaking work originally funded by this DRDF, including further instrument development and field operations and studies. The ability of the PCS to record charge on particles outside of the laboratory with ultra-sensitivity will open up new areas of research in environmental electrostatics.

D. FINANCIAL STATUS

The total funding for this task was $100,000, all of which has been expended.

E. PERSONNEL

No other personnel were involved.

F. PUBLICATIONS

None.

G. REFERENCES

[1] K.B. Tennal, M.K. Mazumder, D.A. Lindquist, J. Zhang, and F. Tendeku, "Triboelectric Separation of Granular Materials," Conference Record of the 1997 IEEE Industry Applications Society 32nd Annual Meeting, New Orleans, LA, Vol. 3, pp. 1724-1729, October 5-9, 1997.

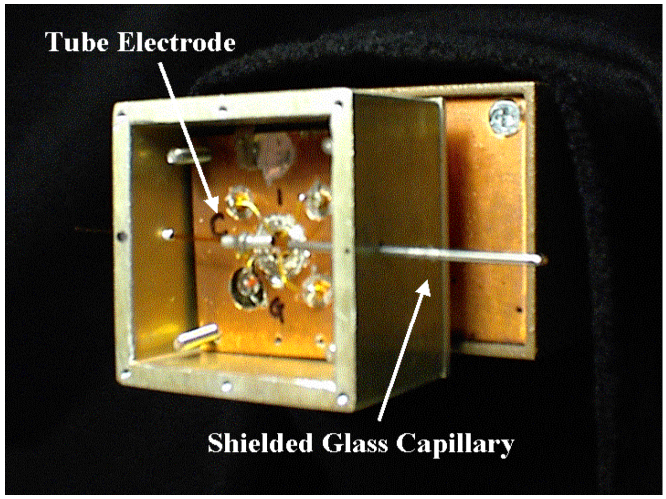

Figure 1. Glass capillary tube and metal tube electrode Faraday cage.

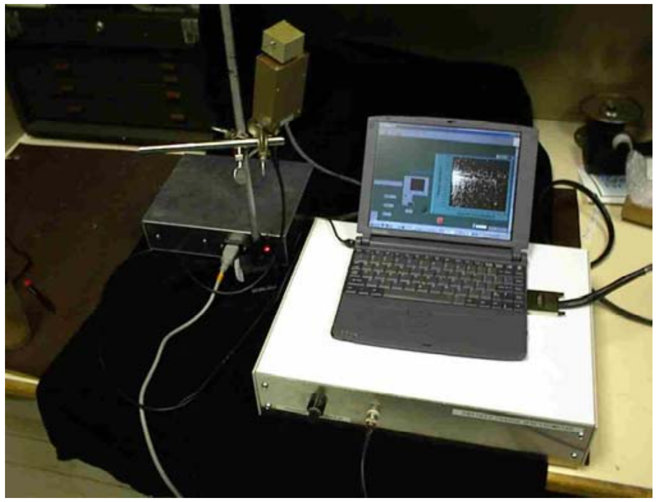

Figure 2. Complete PCS bench-top setup. White box under the computer is the signal-processing electronics.

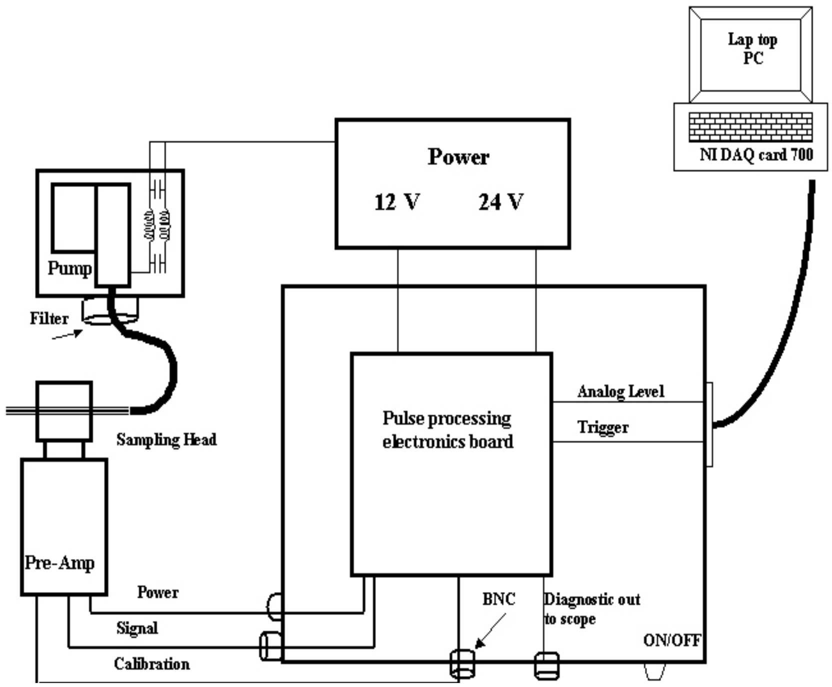

Figure 3. PCS system schematic.

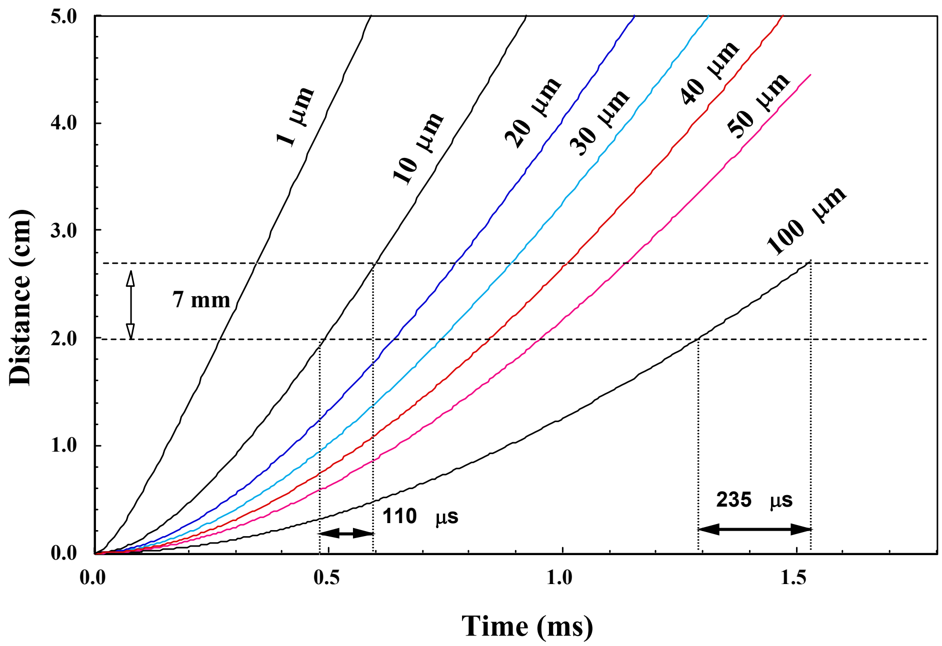

Figure 4. Calculated displacement trajectories for various-size particles accelerated from rest by a 100 m/s flow. All particle trajectories eventually reach the final slope, nearly achieved by the 1 μm trajectory in the first millisecond, which is the velocity of the flow. A 7 mm-long tube electrode, with its entrance placed 2 cm downstream of the inlet, will record a 110 μs transit time for 10 μm particles and a 235 μs transit time for 100 μm particles.

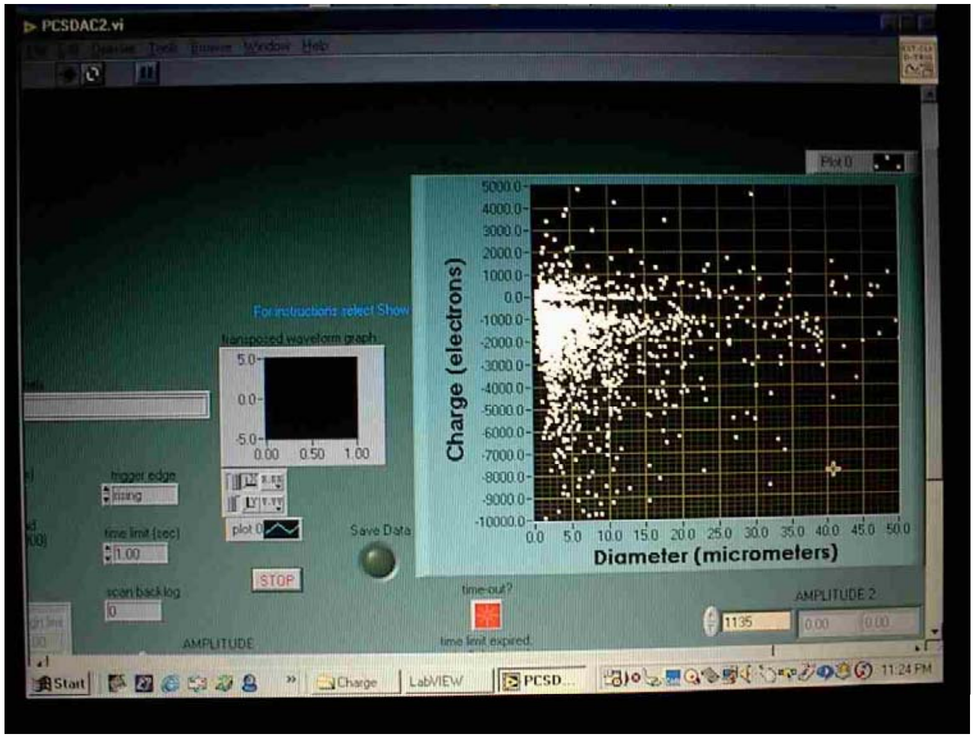

Figure 5. An example of the LabView real-time data analysis and display.

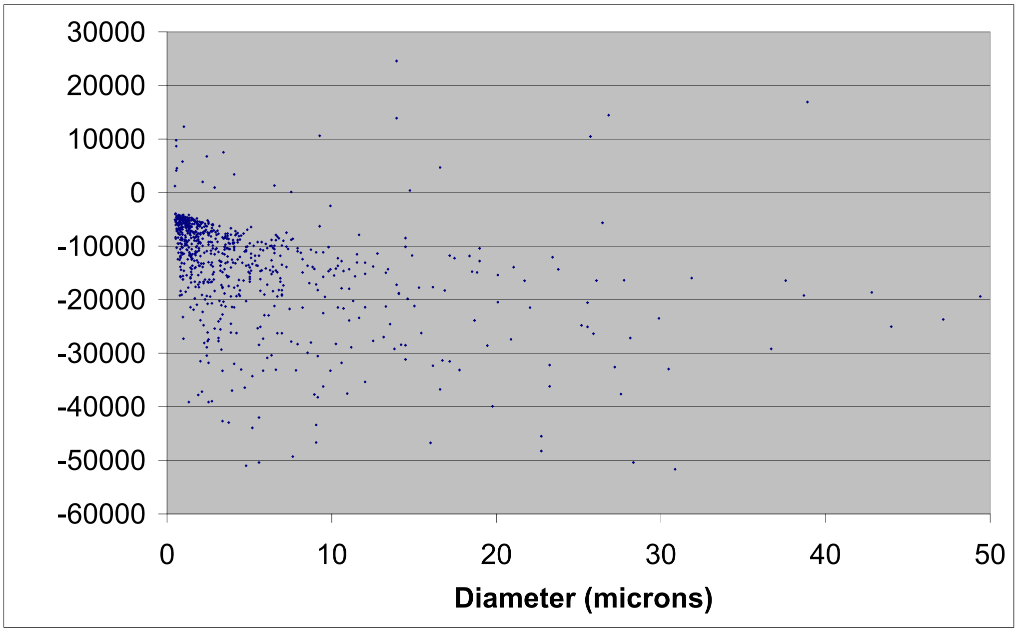

Figure 6. Particle charge and size data acquired in the vicinity of a dust devil during the 2002 MATADOR campaign organized by the University of Arizona.